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Abstract

The impact of financial development and inflation on economic growth is studied within an endogenous growth framework, in which the sector that affects both real money demand and capital productivity is interpreted as the financial sector. First, financial liberalization is found to have a positive effect on growth, the size of which depends on the pre–liberalization real interest and inflation rates. Moreover, an extension of the standard model is shown to generate a strong negative relationship between inflation and growth. In contrast to the theoretical literature, which usually predicts a rather small effect, this result is consistent with the empirical regularities.

Key words: Financial development; Endogenous growth; Inflation;

JEL classification: O11; E31

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1 Introduction

It is well recognized in the literature that the financial sector plays an important role for economic development and growth. The traditional theory of financial repression emphasized the negative growth effects of fiscal policies that repress the financial system [McKinnon (1973), Fry (1988)]. According to this view, financial repression results in low productivity of capital and therefore weak economic performance. The remedy proposed by this theory is simple: the abandonment of interest rate ceilings, of high reserve requirements, and the like, it was claimed, would enhance economic growth. However, the empirical results of financial liberalizations in developing countries were often disappointing, resulting in higher inflation rates, debt crises, and low growth rates after the suggested reforms had been implemented. While the central message that financial repression prevents growth still seems unchallenged, it is now less clear, which other factors may affect the outcome of a liberalization.[1] Recently several studies, including Grenwood and Jovanovic (1990), Bencivenga and Smith (1991), Roubini and Sala-I-Martin (1992), and King and Levine (1993b), have taken up the issue of financial repression and discussed it within endogenous growth frameworks. Explicitly analyzing the role of the financial sector in the allocation process of savings towards their most efficient use, they too reach the conclusion that government policies which repress the financial sector by taxing or regulating cause about low growth. However, these papers again do not answer the question of how other macroeconomic variables, especially the inflation rate and the real interest rate, may influence the effect of financial liberalization on growth.

In this paper these effects are studied in a stylized two sector model of endogenous growth under different assumptions concerning the role of money in the economy. In the basic framework, money is assumed to be used only by consumers in facilitating their transactions. However, it may also be reasonable to assume transaction costs on investment purchases that may be lowered by real money holding. Alternatively, real balances may even enter into the production function of the financial sector as an input factor. In the following, these different extensions of the basic model will be studied.

The sector which affects the consumers' money demand and the transaction costs on investment is interpreted as the financial sector, producing the

[1]The controversial effects of financial liberalization were analyzed by, among others, Diaz-Alejandro (1985), and Dornbusch and Reynoso (1989).

output "financial superstructure". If money is a factor of production, the financial sector rather than the sector producing consumption and investment goods is assumed to use money for production. Since the financial sector plays a crucial role in the allocation of real resources, it is also supposed to affect the productivity of capital. For simplicity, the financial sector is modeled as a black box, that is, unlike Bencivenga and Smith (1991) or Grenwood and Jovanovic (1990), I do not consider the provision of liquidity services or the allocation of capital explicitly. However, the working of the financial sector is more explicitly formulated than in Roubini and Sala-I-Martin (1992). Within a one sector model of endogenous growth, they simply postulated that a single parameter represents the degree of financial repression, having a positive effect on the marginal product of capital and a negative effect on the marginal utility of money. According to Roubini and Sala-I-Martin (1992), this parameter can then be changed arbitrarily by the government. In contrast, the government in this paper is only assumed to influence the productivity of the financial sector; financial liberalization therefore is reflected by an exogenous increase of productivity in the financial sector.

The model's results first suggests that financial liberalization has a positive effect on growth, because it enhances financial development, which increases the real interest rate. However, the size of this effect turns out to depend on both, the values of the real interest rate and the inflation rate before the liberalization. In particular, when money is modeled as an input factor of the production of financial superstructure, higher pre–liberalization real interest rates and lower inflation rates are shown to strengthen the effect of financial liberalization on growth.

In addition, it is shown that if money is used by households only, it is superneutral in steady state, but not on the transitional path to steady state. This replicates a result of the neoclassical growth theory [Fischer (1979)]. In contrast, if money is used to reduce transaction costs of investment purchases or as an input of the production of financial superstructure, the superneutrality result breaks down. In these two settings, inflation has a negative impact on economic growth even in steady state. While similar adverse effects of inflation on growth have already been demonstrated in one sector models of endogenous growth, the results obtained here are more general. They suggest that inflation influences growth when real resources affect transaction costs or when money does not directly affect the technology producing consumption and investment goods. Moreover, as has been found in empirical studies, the growth effect of inflation is shown to weaken when inflation rises. Moreover, the use of money in the financial sector generates a strong negative relationship between inflation and growth. In contrast to the theoretical literature, which usually predicts a rather small effect, this result is consistent with the empirical regularities.

The remainder of the paper is organized as follows: Section 2 describes the structure of the basic model and analyzes the effect of financial liberalization on the steady state per capita growth rate. In section 3, the basic model is extended by assuming transaction costs on investment purchases. It is then investigated how financial development and growth are interrelated. The same issue is analyzed in section 4 for the case in which money enters the production function of the financial sector. Section 5 then compares the growth effect of inflation in the extended setups while section 6 looks at the effect of financial liberalization at different inflation rates. Finally section 7 concludes.

2 The basic model

2.1 The consumer's problem

The representative *consumer* is assumed to live forever and to maximize his utility under perfect foresight. As is standard, his well–being is the sum of all instantaneous future felicities from the real consumption stream c, discounted at the subjective discount rate ρ, and his utility function is time separable with a constant marginal elasticity θ. There is no population growth and no labor–leisure choice in the model. For convenience, the population size may be normalized to one.

The individual's real wealth a consists of real money holdings m_c and real capital k. Real money is held for transaction purposes while real capital is rented to the producer, yielding a real interest rate r. Interest payments are the only source of income. Income is spent on consumption and asset accumulation. The total expenditures associated with consumption consist of the real value of consumption, transaction costs, and the accumulation of real balances for transaction purposes. In order to get a closed form solution for the consumption growth rate, the transaction cost function is supposed to have the following functional form:

$$\Phi_c(c, m_c, z) = T_c \frac{c^{1+\nu_1+\nu_2}}{z^{\nu_1} m_c^{\nu_2}}, \qquad (1)$$

where $\nu_1, \nu_2 > 0$ are technological parameters and $T_c > 0$ is a constant. $\Phi(c, m_c, z)$ satisfies the necessary and sufficient conditions for a transaction costs function with respect to c and m, that is, transaction costs are increasing in consumption and decreasing in money [Feenestra (1986)]. In addition, the transaction technology is assumed to be convex.[2] While these conditions are common in the literature, the transaction costs here are modeled to depend also on the variable z, which represents the level of financial development. Ceteris paribus a higher level of financial development implies a higher z and lower transaction costs. Because the consumers represents a large number of individuals, he takes z as given when optimizing. z can therefore be thought of an external effect of the financial system on the consumer's optimizing problem. The process of financial development that changes z will be specified later.

The consumer solves the following optimization problem:

$$\max_{c, m_c} \int_0^\infty \frac{c^{1-\theta} - 1}{1-\theta} e^{-\rho t} dt, \qquad \theta > 0 \tag{2}$$

$$\text{s.t.} \quad \dot{a} = (a - m_c) r - \pi m_c - c - T_c \frac{c^{1+\nu_1+\nu_2}}{z^{\nu_1} m_c^{\nu_2}}. \tag{3}$$

Along with (3) this yields the first order conditions[3]

$$r + \pi = T_c \nu_2 \left(\frac{c}{z}\right)^{\nu_1} \left(\frac{c}{m_c}\right)^{1+\nu_2}, \tag{4a}$$

$$c^{-\theta} = \lambda \left[1 + T_c (1 + \nu_1 + \nu_2) \left(\frac{c}{z}\right)^{\nu_1} \left(\frac{c}{m_c}\right)^{\nu_2}\right], \tag{4b}$$

$$-\frac{\dot{\lambda}}{\lambda} = r - \rho, \tag{4c}$$

where λ is the costate variable associated with the budget constraint of the consumer.

Equation (4a) reflects that the optimal choice of money equates the marginal costs of holding money with their marginal revenues from saving transaction costs. Moreover, equation (4b) requires the marginal utility of consumption to be equal to the sum of the market value of one unit of the consumption good and the market value of the associated transaction costs. Finally, (4c) is the usual Euler–equation of the dynamic problem.

[2] Convexity may be expressed in the following way: $\Phi_c \geq 0$, $\Phi_m \leq 0$, $\Phi_{cc} \geq 0$ $\Phi_{mm} \geq 0$ $\Phi_{mc} \leq 0$.

[3] See Appendix A for the technical details.

Using equation (4a) and (4b), the following money demand function can be derived:

$$\frac{m_c}{c} = \left(\frac{c}{z}\right)^{\frac{\nu_1}{1+\nu_2}} \left(\frac{T_c \nu_2}{r+\pi}\right)^{\frac{1}{1+\nu_2}} . \tag{5}$$

(5) shows that the demand for real balances is a decreasing function in the opportunity cost of holding money and an increasing function in consumption. In addition, the ratio of consumption relative to financial development, c/z, has a positive impact on money demand: the higher is c/z, the higher is the demand for real money. We may observe that as long as z and c grow at the same rate, financial development will have no effect on money demand. However, since a financial liberalization presumably changes the ratio c/z, it will affect the demand for real balances.

Equation (4b) and (4c) imply the following relation for consumption growth:

$$\gamma_c = \frac{r-\rho}{\theta} + \frac{\nu_1 (\gamma_c - \gamma_z) + \nu_2 (\gamma_c - \gamma_m)}{\theta \left[1 + (1+\nu_1+\nu_2) \left(\frac{c}{z}\right)^{-\frac{1}{1+\nu_2}} \left(\frac{T_c \nu_2}{r+\pi}\right)^{\frac{\nu_2}{1+\nu_2}}\right]}. \tag{6}$$

where γ_x refers to the growth rate of the variable x. In endogenous growth theory, the steady state of an economy is usually defined by a constant real interest rate r and a constant growth rate of all real variables. Equation (6) implies that in our model, a steady states does not necessarily exist. For example, if c and z or c and m expand at different rate, there is no steady state. Furthermore, (6) indicates that if a steady state does not exist or if the economy is moving on a transitional path towards the steady state, money will be not superneutral. This follows immediately from the fact that the right hand side of (6) depends on inflation and hence on nominal money growth.[4]

To focus the analysis, we restrict attention to steady states from now on, that is, all relevant variables are assumed to have a common constant growth rate. As is shown later, the technologies of this economy in fact ensure that c/z is constant then, implying $\gamma_c = \gamma_z = \gamma_m$. Having restricted attention to steady states, we get the standard result of the endogenous growth theory for steady state consumption growth:

$$\gamma_c = \frac{r-\rho}{\theta}. \tag{7}$$

[4] Note that this result is similar to the one of Fischer (1979), who has shown money not to be superneutral outside the steady state in a Sidrauski–type model.

2.2 The producer's problem

Our model economy has two sectors. For analytical convenience, the technologies of both sectors are assumed to be operated by the same representative producer, who decides about the allocation of resources between the sectors.

As is standard in the literature, the first sector produces a *homogeneous good* for investment and consumption with a constant returns to scale technology:

$$y = A\left(\phi_k k\right)^{\alpha}\left(\phi_{zy} z\right)^{1-\alpha}, \tag{8}$$

where ϕ_{ky} and ϕ_{zy} are the shares of physical capital and financial superstructure used in the production of the second sector respectively. The assumption that financial development affects production directly can be justified in several ways. For example, one may argue that production cannot take place in the absence of a financial sector. Even though this may not necessarily hold true at firm level, it seems reasonable at aggregate level. Even in rural areas, credit markets intermediate between savers and borrowers. Furthermore, banks may monitor their customers, which tends to improve the productivity of capital [De Long (1990)]. Finally, recent empirical evidence presented by King and Levine (1993a) suggests that financial development has a robust and positive effect on the productivity of capital.

We still need to define the law of motion for physical capital. Setting the depreciation rate to zero, we use the standard specification

$$\dot{k} = i_k, \tag{9}$$

where i_k is the flow of real resources used in investment.

The second sector produces the output good financial superstructure, z, which develops over time according to the following law of motion:

$$\dot{z} = B\Big(\left(1-\phi_k\right)k\Big)^{\beta}\Big(\left(1-\phi_{zy}\right)z\Big)^{1-\beta}, \tag{10}$$

where $1-\phi_k$ and $1-\phi_{zy}$ are the fractions of the total capital stock and z that are devoted as inputs to the production of this sector. We may note that the development of z is similar to the one of human capital postulated by Lucas (1988) and Rebelo (1991). However, the key difference between this type of two sector growth models and our model is the assumption that z affects money demand. This justifies the interpretation of the second sector as the financial sector. Its output good financial superstructure represents financial development.[5]

The functional form of equation (10) incorporates three important assumptions on the financial sector. First, in order to achieve a certain level of financial development z, physical capital must be accumulated. This seems reasonable, because financial institutions cannot supply sophisticated financial services without computer facilities, properly developed office network and the like. Second, (10) defines the law of motion for z as a function of the level of z attained in the past. This reflects that z represents skills, professional knowledge accumulated in the financial sector, and a variety of financial instruments and innovations. Moreover, the role of learning by doing in financial development may be captured by (10) as well. Third, the scale parameter B is assumed to be a policy variable, which incorporates all possible measures and regulations imposed by the government on the financial system. A higher B implies a more liberalized financial sector, which is supposed to grow more rapidly than a repressed one.

Although the formulation of the financial sector is quite simple here, the producer still decides how much resources he allocates to each sector. In particular, financial development will be determined by his optimizing decisions, whereas the government can only influence the marginal productivity of capital devoted to the financial sector. Note, that this setting is more general than the one of Roubini and Sala-I-Martin (1992), where the level of financial development was arbitrarily chosen by the government.

Having outlined the structure of the model, the optimal problem for the representative producer can be written as:

$$\max_{i_k,\phi_k,\phi_{zy}} \int_0^{\infty} \Big(A_y(\phi_k k)^{\alpha} (\phi_{zy} z)^{1-\alpha} - i_k \Big) e^{-rt} dt \tag{11}$$

$$\text{s.t.} \qquad \dot{k} = i_k \tag{12}$$

$$\dot{z} = B\Big((1-\phi_k)\, k \Big)^{\beta} \Big((1-\phi_{zy})\, z \Big)^{1-\beta}. \tag{13}$$

Along with (12) and (13), (11) delivers the following first order conditions for optimality:

$$\alpha A \left(\frac{\phi_k k}{\phi_{zy} z} \right)^{\alpha-1} = q_z \beta B \left(\frac{(1-\phi_k) k}{(1-\phi_{zy}) z} \right)^{\beta-1}, \tag{14a}$$

[5]The term financial superstructure was invented by Goldsmith (1969) to describe a wide variety of financial instruments.

$$(1-\alpha)A\left(\frac{\phi_k k}{\phi_{zy}z}\right)^{\alpha} = q_z(1-\beta)B\left(\frac{(1-\phi_k)k}{(1-\phi_{zy})z}\right)^{\beta}, \tag{14b}$$

$$r = \alpha A\left(\frac{\phi_k k}{\phi_{zy}z}\right)^{\alpha-1}, \tag{14c}$$

$$r = (1-\beta)B\left(\frac{(1-\phi_k)k}{(1-\phi_{zy})z}\right)^{\beta} + \frac{\dot{q}_z}{q_z}, \tag{14d}$$

where q_z is the shadow price of the financial superstructure. Equation (14a) and (14b) express that the marginal product of physical capital and financial superstructure have to be equated between the two sectors. Equation (14c) is the optimality condition that the marginal return of capital be equal to its marginal costs, which is the rental price of capital. Finally, by (14d), the marginal return on financial superstructure has to correspond to the rental price of capital too. Because of arbitrage between physical capital and financial superstructure, the marginal return on financial superstructure is the sum of its marginal product and the capital gain of one unit of financial superstructure.

In addition to the interpretation of the first order conditions just given, equation (14c) may have other implications. First, it shows that the higher z is relative to k, the higher is the marginal product of capital in the production sector. In line with the financial repression theory, this means that the aggregate capital stock is less productive if the financial intermediaries participate less in the allocation of capital. Countries with higher ratios z/k, that is, with a relatively more developed financial sector, therefore have a higher marginal product of capital and a higher real interest rate. However, the marginal effect of z/k on r decreases, reflecting that two economies with different but large z/k should not have very different real interest rates. Second, equation (14c) has another implication when there is a sufficient degree of international capital mobility: If a country with low z/k invests in a second country with high z/k, then the real interest rate in the first (second) country increases (decreases), because k decreases (increases).

The first order conditions can be used to determine the real interest rate. Dividing (14a) by (14b) yields the well known equilibrium condition for two sector models of endogenous growth:

$$\frac{\alpha}{1-\alpha}\frac{\phi_{zy}}{1-\phi_{zy}} = \frac{\beta}{1-\beta}\frac{\phi_k}{1-\phi_k}. \tag{15}$$

In equilibrium, the marginal rate of transformation must be equal between the two sectors. In addition, in steady state, the real interest rate must be constant, implying that the ratio z/k of capital to financial superstructure and the shadow price q_z of financial superstructure are also constant. Solving (14c) and (14d) for r and using (15) yields for the equilibrium real interest rate:

$$r = \Theta_{r0} B^{\delta}, \tag{16}$$

where $\Theta_{r0} > 0$ and $0 < \delta < 1$ is a function of the technological parameters of the two sectors as defined in Appendix B.

2.3 The government

To close the model, the public sector has to be described. The *government* is assumed to finance its expenditure g entirely by issuing nominal base money at a rate μ. Since the analysis does not focus on the growth effect of taxation, the possibility of levying taxes is excluded for simplicity. Moreover, for similar reasons, the government cannot borrow from either domestic or foreign agents. Hence the budget identity

$$g = \mu m \tag{17}$$

has to hold. It is also assumed that government expenditures do not effect the consumer's utility, his budget constraint, or the production technology. We may imagine that government expenditure vanishes in the air.

2.4 Comparative steady state

As shown above, all growth rates have to be equal and constant in steady state. By (14c) and (14d), z/k and k/y are also constant then, implying that $\gamma_k = \gamma_z = \gamma_y$. Furthermore, consumption also grows at this common rate. This follows from the fact that the consumer's expenditure consist of real consumption and transaction costs. The national income identity hence obeys the following form:

$$1 \equiv \frac{c}{z}\frac{z}{y}\left[1 + T_c\left(\frac{c}{z}\right)^{\nu_1}\left(\frac{c}{m}\right)^{\nu_2}\right] + \frac{g}{y} + \frac{k}{y}\gamma_k. \tag{18}$$

Since z/y is known to be constant and g/y is assumed to be constant, c/z must also be constant in steady state. Hence, $\gamma_y = \gamma_c = \gamma_k = \gamma_z$ in steady state.

Having shown that the steady state exists, the main interest of the analysis is to look at the different steady state growth rates associated with different levels of financial liberalization. In the subsequent analysis, financial liberalization is defined as an increase in B, which represents the effects of government policy. Since the growth rate is determined by (7) at any given real interest rate, it is sufficient to focus on how financial liberalization affects the real interest rate. This effect can be obtained by taking the derivative of (16) with respect to B:

$$\frac{dr}{dB} = \delta \frac{r}{B}. \tag{19}$$

From equation (19), the effect of B on r is unambiguously positive if and only if r is positive. Moreover, if r is close to zero, then the effect of financial liberalization on long run growth will be infinitesimally small. In addition, it may be noticed that financial liberalization changes the steady state ratio of physical capital to financial superstructure. After having been liberalized, the economy thus moves on a transitional path towards a new steady state on which money is not superneutral [Compare (6)]. This implies that the effect of financial liberalization on the transitional path will also depend on the monetary policy. Since we focus on steady states here, this effect will not be investigated any further.

The impact of financial liberalization on inflation will now be derived under the assumption that the government keeps μ constant. The long run rate of inflation is then simply determined by the difference between nominal and real money growth. Since, for a constant ratio c/z, real balances grow at the same rate as consumption [compare (5)], we have $\pi = \mu - \gamma_c$ in steady state. For a given nominal money growth rate μ, the relation between financial liberalization and inflation therefore is:

$$\frac{d\pi}{dB} = -\frac{1}{\theta}\frac{dr}{dB}. \tag{20}$$

Equation (20) asserts that a financial liberalization reduces long run inflation unambiguously. However, since dr/dB may be very small, the positive effect of financial liberalization on inflation may well be negligible.

3 Transaction costs for investment

3.1 Extension of the basic model

In the previous section the role of money was restricted to facilitate only the transactions of the consumer. Now, the framework will be extended by assuming that investment purchases are also associated with transaction costs. These are defined by

$$\Phi_i(i_k, m, z) = T_i \frac{i_k^{1+\vartheta_1+\vartheta_2}}{(\phi_{zi} z)^{\vartheta_1} m_p^{\vartheta_2}},$$

where $\vartheta_1, \vartheta_2 > 0$ and $T_i > 0$ are constants. Following Stockman (1981), $\Phi_i(i_k, m, z)$ reflects the assumption that real balances lower the transaction costs related to purchases of new equipment. A justification for this is, for example, provided by McKinnon's (1973) complementarity hypothesis. His idea essentially was that money and investment goods are complements rather than substitutes in financially repressed economies, because usually their financial system operate so poorly that investment goods are cash– rather credit–goods. At the aggregate level we may represent complementarity by a convex transaction cost function. Since empirically the degree to which investment goods are cash–goods depends on the state of financial development, we assume that transaction costs depend not only on investment and money, but also on financial superstructure. In particular, the allocation of more financial superstructure $\phi_{zi} z$ to investment purchases is supposed to lower these costs. Hence the empirical regularity that firms in developed countries hold only a small amount of cash is captured too.

The optimal problem for the producer now has the form

$$\max_{\substack{i_k, i_m \\ \phi_k \phi_{zy}, \phi_{zi}}} \int_0^\infty \left(A(\phi_k k)^\alpha (\phi_{zy} z)^{1-\alpha} - i_k - T_i \frac{i_k^{1+\vartheta_1+\vartheta_2}}{(\phi_{zi} z)^{\vartheta_1} m_p^{\vartheta_2}} - i_m \right) e^{-rt} dt, \quad (21)$$

s.t.

$$\dot{k} = i_k, \quad (22)$$

$$\dot{m}_p = i_m - \pi m_p, \quad (23)$$

$$\dot{z} = B\Big((1-\phi_k)k\Big)^\beta \Big((1-\phi_{zy}-\phi_{zi})z\Big)^{1-\beta}, \quad (24)$$

where ϕ_{zi} is the fraction of the financial superstructure devoted to facilitate transactions. The law of motion (23) for real balances m_p hypothesizes that the change of m_p is the difference between the real resources devoted to the accumulation of money i_m and the erosion of real balances through inflation πm_p (inflation tax).

The first order conditions for optimality are:

$$\alpha A \left(\frac{\phi_k k}{\phi_{zy} z}\right)^{\alpha-1} = q_z \beta B \left(\frac{(1-\phi_k)k}{(1-\phi_{zy}-\phi_{zi})z}\right)^{\beta-1}, \tag{25a}$$

$$(1-\alpha) A \left(\frac{\phi_k k}{\phi_{zy} z}\right)^{\alpha} = q_z (1-\beta) B \left(\frac{(1-\phi_k)k}{(1-\phi_{zy}-\phi_{zi})z}\right)^{\beta}, \tag{25b}$$

$$(1-\alpha) A \left(\frac{\phi_k k}{\phi_{zy} z}\right)^{\alpha} = \vartheta_1 T_p \left(\frac{i_k}{\phi_{zi} z}\right)^{1+\vartheta_1} \left(\frac{i_k}{m_p}\right)^{\vartheta_2}, \tag{25c}$$

$$r + \pi = \vartheta_2 T_p \left(\frac{i_k}{\phi_{zi} z}\right)^{\vartheta_1} \left(\frac{i_k}{m_p}\right)^{1+\vartheta_2}, \tag{25d}$$

$$q_k = 1 + (1+\vartheta_1+\vartheta_2) T_p \left(\frac{i_k}{\phi_{zi} z}\right)^{\vartheta_1} \left(\frac{i_k}{m_p}\right)^{\vartheta_2}, \tag{25e}$$

$$r = \frac{1}{q_k} \alpha A \left(\frac{\phi_k k}{\phi_{zy} z}\right)^{\alpha-1} + \frac{\dot{q}_k}{q_k}, \tag{25f}$$

$$r = (1-\beta) B \left(\frac{(1-\phi_k)k}{(1-\phi_{zy}-\phi_{zi})z}\right)^{\beta} + \frac{\dot{q}_z}{q_z}. \tag{25g}$$

Equation (25a) and (25b) equate the marginal products of physical capital and financial superstructure between the two sectors. Moreover, since real resources are also used in transactions, (25c) delivers the condition that the marginal reduction of transaction costs through financial superstructure must be equal to the marginal product of financial superstructure in both sectors. The equilibrium holdings of real balances are determined by the familiar condition that the producer's opportunity cost of holding money equal the marginal revenue through economizing on transactions [(25d)]. Equation (25e) provides a relation for the shadow price of capital similar to the one in the neoclassical "q–theory". Note that since investments are associated with transaction costs, the shadow price of capital is always larger than unity here. Furthermore, (25f) states that the equality of the real interest rate to the sum of the marginal product of capital and the capital gain on one unit physical capital. Finally, the interpretation of equation (25g) essentially is the same as of equation (14d).

Following the procedure used in the previous section, the equilibrium interest rate can be determined. Dividing (25a) by (25b), one gets that in equilibrium the marginal rates of transformations ought to be equated between the two sectors:

$$\frac{\alpha}{1-\alpha}\frac{\phi_{zy}}{1-\phi_{zy}-\phi_{zi}}=\frac{\beta}{1-\beta}\frac{\phi_k}{1-\phi_k} \tag{26}$$

which is similar to (15). Since r is constant in steady state, q_k and q_z are also constant. Using (26), (25f) and (25g) can be solved for r:

$$r=\Theta_{r1}B^{\delta_1}q_k^{-\delta_2}, \tag{27}$$

where $\Theta_{r1}>0$ and $0<\delta_1,\delta_2<0$ are functions of the technological parameters as defined in Appendix C. Note that in contrast to the basic model, the real interest rate also depends on the shadow price of capital. This relationship is negative as in any "q–model" of investment. In order to get a functional dependence between the real interest rate and the exogenous variables and parameters, q_k has to be determined. (25e) and (25d) give q_k as a function of the nominal interest rate $r+\pi$ and the ratio of investment to money i_k/m_p. In addition, the latter can be obtained as a function of the nominal and the real interest rate, $r+\pi$ and r, from equations (25a), (25b), (25c) and (25g). Combining these two results, the shadow price of capital turns out to be

$$q_k=1+\Theta_q B^{-\eta_1}r^{\eta_1}(r+\pi)^{\eta_2}, \tag{28}$$

where $\Theta_q>0$ and $0<\eta_1$, $0<\eta_2<1$ as derived in Appendix C. (28) shows that the shadow price of capital q_z in equilibrium depends on both, the real and the nominal interest rate. The real interest rate affects q_z because real resources are used in the production of financial superstructure, which in turn influences transaction costs. The higher is the real interest rate, the more real resources are used in productive activities instead of in transactions, which increases transaction costs and q_k. However, q_k also depends on the nominal interest rate, because higher nominal interest rates make it more expensive to use money in transactions. The producer therefore reduces his money holding which increases his transaction costs and q_k.

3.2 Comparative steady state

Since r is constant, all variables grow at a common constant rate in steady state. This can be seen by using the modified national income identity

$$1\equiv\frac{c}{z}\frac{z}{y}\left[1+T_c\left(\frac{c}{z}\right)^{\nu_1}\left(\frac{c}{m}\right)^{\nu_2}\right]+\frac{g}{y}+\frac{k}{y}\gamma_k\left[1+T_i\left(\frac{i_k}{\phi_{zi}z}\right)^{\vartheta_1}\left(\frac{i_k}{m_p}\right)^{\vartheta_2}\right]. \tag{29}$$

together with the same arguments as in the previous section.

As before, the main interest is in the effect of a marginal change in B on r. Since the system of equations (27) and (28) cannot be solved explicitly for r and q_k, we have to take the total derivative of the two equations and then to solve for dr/dB. (27) and (28) yield the total derivative

$$dr = \delta_1 \frac{r}{B} dB - \delta_2 \frac{r}{q_k} dq_k, \tag{30a}$$

$$dq_k = -\eta_1 \frac{q_k - 1}{B} dB + \eta_1 \frac{q_k - 1}{r} dr + \eta_2 \frac{q_k - 1}{r + \pi}(dr + d\pi). \tag{30b}$$

Assuming that $d\pi = 0$, the equilibrium effect of financial liberalization on the real interest rate is given by

$$\left.\frac{dr}{dB}\right|_I = \frac{r}{B} \frac{\delta_1 + \delta_2 \eta_1 \frac{q_k - 1}{q_k}}{1 + \delta_2 \left(\eta_1 + \eta_2 \frac{r}{r + \pi}\right) \frac{q_k - 1}{q_k}}, \tag{31}$$

where the subscript I refers to the first extension. Since q_k is greater than unity, this expression is always positive, that is, financial liberalization has a positive effect on real interest rate and on economic growth. Moreover, similarly to the basic setup, (31) indicates that this effect is very small when the pre-liberalization real interest rate was small. The relationship also shows that the effect of a liberalization depends on q_k and hence on inflation. We may observe that if q_k were equal to one, (31) would reduce to the expression (19) of the basic model. From the basic model it is still clear that financial liberalization negatively affects the long run rate of inflation [(20)]. However, the size of this effect may be very small. It should be stressed that we have not yet analyzed how inflation influences the effect of financial liberalization.

4 Money used in production of the financial sector

4.1 Extension of the basic model

Qualitatively, the results of the basic setup did not change by assuming that money facilitates transactions in investment goods. In this section, we therefore want to study the role of money when it is an input for production. Since we have modeled a financial sector, it seems reasonable to assume that money effects the productivity of capital used in the financial sector. In the real world, financial businesses hold money for several purposes, for example to operate check clearing systems, to trade securities, or to fulfill reserve requirements. In our highly stylized model this may be expressed by assuming that money is used as an input factor in the accumulation of financial superstructure. Extending the basic model in this way, the decision problem for the producer becomes

$$\max_{\substack{i_k, i_m \\ \phi_k, \phi_{zy}}} \int_0^\infty \Big(A(\phi_k k)^\alpha (\phi_{zy} z)^{1-\alpha} - i_k - i_m \Big) e^{-rt} dt, \tag{32}$$

$$\text{s.t.} \qquad \dot{k} = i_k, \tag{33}$$

$$\dot{m}_p = i_m - \pi m_p, \tag{34}$$

$$\dot{z} = B\Big((1-\phi_k)k\Big)^{\beta_1} \Big((1-\phi_{zy})z\Big)^{\beta_2} m_p^{1-\beta_1-\beta_2}. \tag{35}$$

This yields the following first order conditions:

$$\alpha A \left(\frac{\phi_k k}{\phi_{zy} z}\right)^{\alpha-1} = q_z \beta_1 B \left(\frac{(1-\phi_k)k}{(1-\phi_{zy})z}\right)^{\beta_1 - 1} \left(\frac{m}{(1-\phi_{zy})z}\right)^{1-\beta_1-\beta_2}, \tag{36a}$$

$$(1-\alpha) A \left(\frac{\phi_k k}{\phi_{zy} z}\right)^{\alpha} = q_z \beta_2 B \left(\frac{(1-\phi_k)k}{(1-\phi_{zy})z}\right)^{\beta_1} \left(\frac{m}{(1-\phi_{zy})z}\right)^{1-\beta_1-\beta_2}, \tag{36b}$$

$$r + \pi = q_z (1-\beta_1-\beta_2) B \left(\frac{(1-\phi_k)k}{(1-\phi_{zy})z}\right)^{\beta_1} \left(\frac{m}{(1-\phi_{zy})z}\right)^{-\beta_1-\beta_2}, \tag{36c}$$

$$r = \alpha A \left(\frac{\phi_k k}{\phi_{zy} z}\right)^{\alpha-1}, \tag{36d}$$

$$r = \beta_2 B \left(\frac{(1-\phi_k)k}{(1-\phi_{zy})z}\right)^{\beta_1} \left(\frac{m}{(1-\phi_{zy})z}\right)^{1-\beta_1-\beta_2} + \frac{\dot{q}_z}{q_z}. \tag{36e}$$

Equations (36a) and (36b) are the equilibrium conditions for the marginal product of physical capital and financial superstructure. (36c) equates the opportunity cost of holding money with the marginal product of money. Similarly to the two previous model variants, (36d) and (36e) give the equilibrium conditions for the real interest rate.

The difference between the optimality conditions for this model and for the first extension is that here the marginal product on capital is directly affected by money. In contrast, in the first extension, the effect of real balances is only transmitted through the adjustment in the shadow price of capital. Despite of this difference, the basic equilibrium conditions for the allocation of resources between the two sectors remain unchanged. Dividing equation (36a) by (36b), provides the condition

$$\frac{\alpha}{1-\alpha}\frac{\phi_{zy}}{1-\phi_{zy}}=\frac{\beta_1}{\beta_2}\frac{\phi_k}{1-\phi_k}. \tag{37}$$

Equation (37) is essentially the same as (15) and (26), which means that if more resources have to be allocated to one sector, more from both input factors will be used in the production of this sector depending on the technological parameters α and β.

An expression for the real interest rate can be obtained from the first order conditions in the following way: Using (36d), (36e) and (37), the rental price of capital r can be expressed as a function of both the technological parameters and of the ratio of money to the share of financial superstructure allocated to the financial sector $m/(1-\phi_{zy})z$. Furthermore, equations (36b), (36c), and (36d) can be solved for $m/(1-\phi_{zy})z$ as a function of r, $r+\pi$, and the technological parameters. These two results imply the following relationship for the equilibrium real interest rate

$$r=\frac{\Theta_{r2}B^{\varrho_1}}{(r+\pi)^{\varrho_2}}, \tag{38}$$

where $0<\Theta_{r2}$ and $0<\varrho_1,\varrho_2<1$ as defined in Appendix D.

4.2 Comparative steady state

Since transaction costs are considered only for consumption goods, the national income identity in this extension is the same as in the basic model, that is, it is given by (18). Applying the same arguments as in the basic model, it can be shown that the growth rates for all real variables are equal and constant in steady state.

Having determined an expression for the real interest rate, we can now analyze the equilibrium effect of a financial liberalization. Since (38) cannot be solved explicitly for r, we again take the total derivatives:

$$dr=\varrho_1\frac{r}{B}dB-\varrho_2\frac{r}{r+\pi}(dr+d\pi), \tag{39}$$

and solve for dr/dB under the assumption that $d\pi=0$. It yields

$$\left.\frac{dr}{dB}\right|_{II}=\frac{r}{B}\frac{\varrho_1}{1+\frac{r}{r+\pi}\varrho_2}. \tag{40}$$

As before, the effect of financial liberalization on the real interest rate is positive. Moreover, similarly to the previous setups, this effect would be negligible if the rental price of capital were small before the liberalization. Finally, the impact of financial liberalization on the long run rate of inflation is negative and still given by (20). Although these findings are qualitatively the same as before, there will be some crucial differences among the different variants when the growth effect of inflation and the effect of inflation on the growth effect of financial liberalization are studied below.

Summarizing, the growth effect of financial liberalization has been shown to be qualitatively the same under various assumptions on the role of money in the economy: In all set–ups, it is positive, but its size is positively related to the pre–liberalization real interest rate. This means that low growth economies with a low real interest rate will hardly benefit from a financial reform.

5 The growth effect of inflation in the different variants

The relation between growth and inflation is a classic issue of monetary economics. A large body of literature assesses the effects of anticipated inflation on growth in the neoclassical framework.[6] In this kind of models, essentially three channels have been identified through which inflation may affect the capital stock and output in steady state. First, if the labor–leisure choice is endogenous, a higher rate of inflation lowers labor supply which decreases the marginal return on capital and hence brings about a fall in the steady state capital stock. Second, if investment decisions or the productivity of capital are affected by real balances, an increase in inflation makes investment or production more costly, which lowers the steady state level of capital. Finally, the presence of nominal rigidities and the lack of tax indexation impose a higher real tax burden on individuals when inflation rises.

The endogenous growth literature focuses on similar channels. De Gregorio (1992, 1993) analyzes the growth effect of inflation in a one–sector endogenous growth model, in which a "magic" spillover in production is present. In the different versions, he considers the endogenous labor–leisure choice and technologies where investment or production is affected by real balances. His

[6] For a survey see Orphanides and Solow (1990).

results shows that in all cases, inflation has a negative effect on growth. Gomme (1993) sets up a stochastic two–sector endogenous growth model with elastic labor supply, human capital, and money. He also concludes that higher inflation is associated with lower growth. The same negative relationship turns up in the framework of Jones and Manuelli (1993), where the depreciation rate, which is used for fiscal purposes, is given in nominal terms. In particular, a higher rate of inflation is associated with higher real tax on investment which lowers the incentive to invest and hence depresses economic growth. The same results hold if elastic labor supply is considered.

Apparently, the qualitative result is quite robust: all channels, which generate a negative relationship between economic growth and inflation in neoclassical growth models, work in the endogenous growth context too. This is in line with the empirical literature. For example Körmendi and Meguire (1985) found that empirically a 2% per year deceleration in inflation increases the per capita growth rate 1.7% per annum, implying an extremely strong relationship between growth and inflation. Furthermore, Roubini and Sala-I-Martin (1992) estimated that 10% higher inflation is associated with a 0.5% reduction of the per capita growth rate. A similar result was presented by Fischer (1993), who reports that a reduction of the growth rate by 0.4% is caused by an increase of 10% in the rate of inflation. In addition, Fischer (1993) also investigates the question whether inflation nonlinearities are present. He shows that the relation between growth and inflation weakens as inflation rises, that is, it is strong at low and moderate inflation rates, but negligible for high inflation.

Although the recent empirical investigations report less strong growth effects of inflation than Körmendi and Meguire (1985), it seems save to conclude that not only qualitatively, but also quantitatively, the effect of inflation on growth is important. In contrast, calibrated versions of endogenous growth models generate rather weak quantitative effects of inflation on growth. Gomme (1993), for example, finds that "the welfare cost of inflation are modest". More precisely, a version of his stochastic model with elastic labor supply calibrated for the US predicts that an increase in the inflation by 10.5% *per quarter* lowers growth rate by 0.2% *per year*. Jones and Manuelli (1993) get similar results. In addition, they note that in their set–up, the growth effect of inflation is stronger if inflation is *higher*, which clearly contradicts the empirical evidence in Fischer (1993).

This contradiction demonstrates the need for further effort in finding channels which can explain the empirical findings on growth and inflation.

In this paper two models have been presented where money has not been superneutral in steady state. These two set–ups will now be analyzed as to whether they generate a relationship between growth and inflation consistent with the empirical literature.

In the first extension, where money affects investment decisions, equations (30a) and (30b) can be used to determine how inflation influences growth in steady state. Setting $dB = 0$, we get

$$\left.\frac{dr}{d\pi}\right|_I = -\frac{\delta_2\eta_2\dfrac{q_k - 1}{q_k}\dfrac{r}{r+\pi}}{1+\delta_2\left(\eta_1+\eta_2\dfrac{r}{r+\pi}\right)\dfrac{q_k-1}{q_k}}, \tag{41}$$

that is, inflation has a negative effect on growth. This qualitative result comes about because an exogenous increase in the rate of inflation increases the opportunity costs of holding money. The producer hence reduces real balances, which raises transactions costs, increases the shadow value of capital, and depresses investment. The new equilibrium is characterized by lower investment and economic growth. This negative impact of inflation on growth has already been shown by other authors if transaction costs in investment purchases were considered. [7] The model presented here assesses this effect under the additional assumption that the transaction technology uses financial superstructure, which is produced with real resources. If no real resources were used in transactions, that is, $\vartheta_1 = 0 \Rightarrow \eta_1 = 0$, the denominator of (41) would be smaller, implying a higher growth effect of inflation. Intuitively this result arises because financial superstructure mitigates the consequences of inflation on transactions. More precisely, an increase in inflation raises the opportunity cost of holding money. However, the real interest rate will fall, which lowers the opportunity cost of using real resources in transaction and gives an incentive to use more financial superstructure in transaction. The possibility of substitution between real resources and money in transactions therefore results in a lower increase of transaction costs as a consequence of rising inflation.

The next question to be answered is whether the first extension of our basic model generates similar nonlinearities as found by Fischer (1993). His result may be interpreted in that the rental price of capital is a convex function of inflation. This indicates that the second derivative of the real interest rate with respect to inflation must be positive. Taking the total derivative of

[7] Compare for example De Gregorio (1993).

equation (41) and rearranging yields

$$\left.\frac{d^2r}{d^2\pi}\right|_I = \frac{1}{\delta_2\eta_2 r}\left[\left(\delta_2\eta_2 + \frac{q_k}{q_k-1}\right)\left(1-\frac{\pi}{r}\frac{dr}{d\pi}\right) - \frac{r+\pi}{(q_k-1)^2}\frac{dq_k}{d\pi}\right]\left(\frac{dr}{d\pi}\right)^2. \quad (42)$$

The sign of the expression depends on the sign of the terms in the squared bracket. Since $dr/d\pi < 0$, the first term is positive while the second is negative because $dq_k/d\pi > 0$. Hence, it is not clear whether (42) is positive or not. However, (42) indicates a sufficient condition for the expression in the squared brackets to be positive

$$\frac{q_k}{q_k-1} > \frac{r+\pi}{(q_k-1)^2}\frac{dq_k}{d\pi}. \quad (43)$$

Equation (30a) and (30b) imply that

$$\frac{dq_k}{d\pi} = \eta_2 \frac{q_k-1}{q_k}\frac{r}{r+\pi}\frac{1}{\Delta}, \quad (44)$$

where $\Delta > 1$ is the denominator of (41). Plugging (44) into (43) gives

$$1 > \eta_2 \frac{r}{q_k}\frac{1}{\Delta}. \quad (45)$$

Since η_2 and r are smaller than one, whereas q_k and Δ are larger than one, (45) is always satisfied and (42) positive. This means that if money facilitates transactions of investment goods, then the real interest rate and hence the growth rate is a convex function of inflation. In this case, the results of model variant one are thus consistent with the empirical evidence in Fischer (1993).

Let us turn now to the variant of the basic model in which money enters the production of financial superstructure. The growth effect of inflation is determined by (39). Setting $dB = 0$, we find

$$\left.\frac{dr}{d\pi}\right|_{II} = -\frac{\varrho_2 \dfrac{r}{r+\pi}}{1+\varrho_2\dfrac{r}{r+\pi}}. \quad (46)$$

Clearly, inflation has a negative effect on the real interest rate and on growth. Higher inflation is associated with higher costs in the financial sector, because money is used to produce financial superstructure. Consequently, the producer lowers real balances. As a result, the marginal return on capital and the per capita growth rate decrease.

Taking the total derivative of equation (46) and rearranging results in

$$\left.\frac{d^2 r}{d^2 \pi}\right|_{II} = \frac{1}{\varrho_2 r}\left[1 - \frac{\pi}{r}\frac{dr}{d\pi}\right]\left(\frac{dr}{d\pi}\right)^2 . \tag{47}$$

Since $dr/d\pi$ is negative, the expression is positive, that is, the real interest rate is a convex function of the rate of inflation in our model variant two.

The first and second derivatives just derived for the two extensions mean that in both cases the real per capita growth rate is a decreasing and convex function of inflation. However, these *qualitative* results do not necessarily imply that the theoretical models can explain the *quantitative* features found in empirical studies. In order to get more insight in the quantitative characteristics of both models, some numerical examples are computed from equations (27), (28), and (38). Doing these calculations, I assume that $\Theta_{r_1} B^{\delta_1} = 0.15$, that $\Theta_q B^{-\eta_1} = 1$, and that $\Theta_{r_2} B^{\varrho_1} = 0.04$. At zero inflation, these values generate real interest rates ranging between 10 and 20 percent depending on the other parameters, which is not implausible for high growth countries. Note that any other interest rate might have been obtained from varying Θ_{r_1} or Θ_{r_2}. This, however, is not important, because what matters for the results is how fast the level of the real interest rate changes if inflation increases. In addition, θ_2 and η_2 are varied such that $\theta_2 \eta_2 = \varrho_2$. This means that the two setups can be compared at similar parameter values since $\theta_2 \eta_2$ and ϱ_2 are the two parameters that determine the strength of the effect of the nominal on the real interest rate in both variants. Moreover, there is an additional parameter η_1 to be determined in case the producer faces transaction costs on investment, which expresses the elasticity of these costs with respect to the financial superstructure. The numerical results on the relationship between the real interest rate and inflation are depicted in Figure 1, 2, and 3 for the transaction costs on investment case while Figure 4 shows the function for the money in the financial technology case. [8]

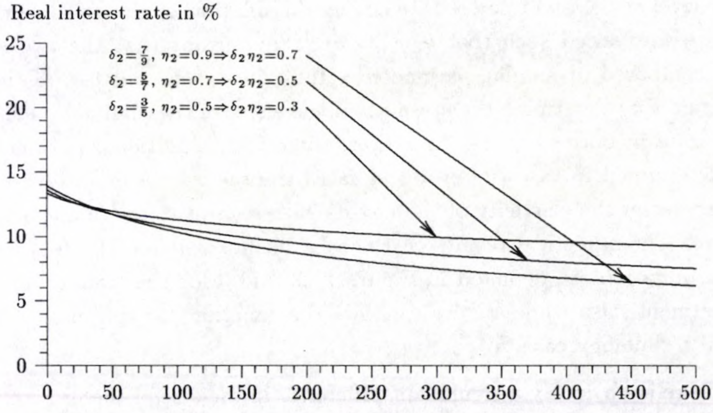
There is obviously a significant difference in the size of the growth effect of inflation, depending on whether money facilities investment transactions or is a factor of production of the financial sector. Figures 1, 2, and 3 show that the model with transaction costs on investment generates only slightly different relationships between inflation and growth when the parameters values vary. In all cases, the growth effect of inflation is relatively small and almost invariant

[8] Please find these figures on pages 24 and 25.

for the different parameter values if the rate of inflation is below 100%. The largest growth effect is present if real resources do not affect transaction costs very much, that is, if η_1 is small, which is in line with the above argument that financial superstructure mitigates the consequences of inflation on transactions. Nevertheless, even in this case an increase of inflation from 0% to 50% pushes down real interest rate from 14% to 12% only. This example therefore suggests that a model economy with investment transaction costs cannot reproduce the growth effect of inflation empirically found.[9]

In contrast, Figure 4 suggests that a substantial growth effect of inflation can be generated in model variant two when money affects the productivity of capital directly. The steepness of the curve falls very fast for all parameter values when inflation is between 0% to 50%. This means that an increase in inflation induces a large drop in the real interest rate at low levels of inflation, whereas in hyperinflation environments, the real interest rate remains almost unaffected by inflation.

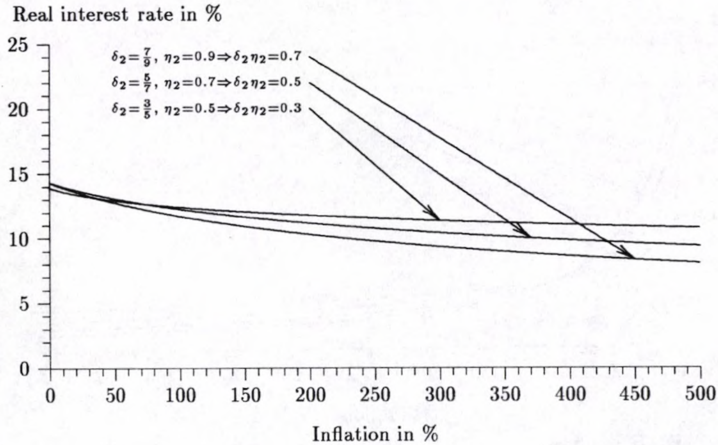
Figure 1: The real interest rate as a function of the inflation in the first extension if $\eta_1 = 0.25$



$\Theta_{r_1} B^{\delta_1} = 0.15,\ \Theta_q B^{-\eta_1} = 1$

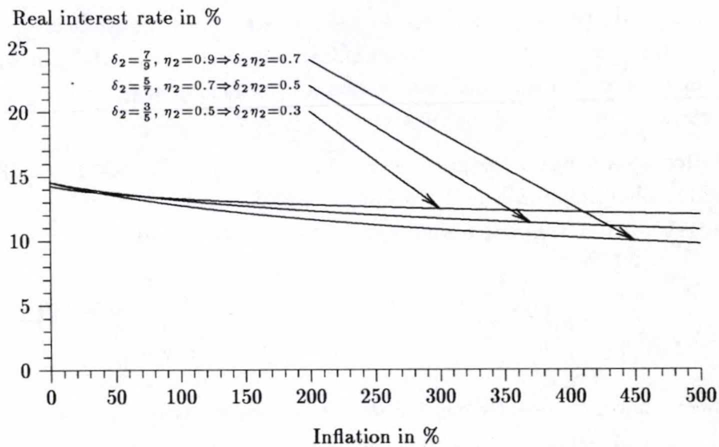
[9]Computations were carried out for a wide range of parameter values to ensure that the results are not sensitive to the parameter values chosen above.

Figure 2: The real interest rate as a function of the inflation in the first extension if $\eta_1 = 0.5$



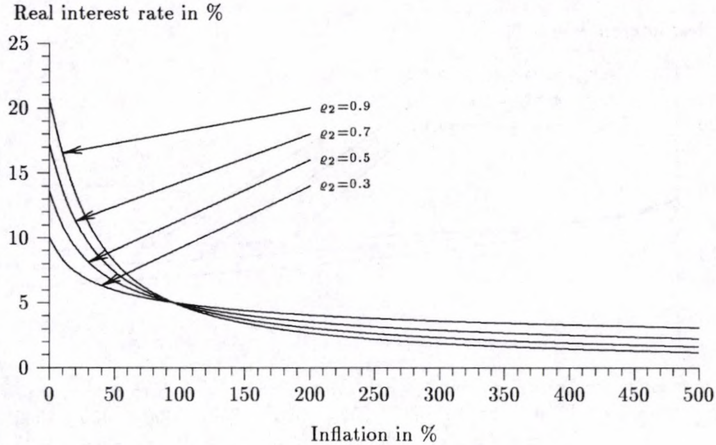
$\Theta_{r1} B^{\delta_1} = 0.15,\ \Theta_q B^{-\eta_1} = 1$

Figure 3: The real interest rate as a function of the inflation in the first extension if $\eta_1 = 0.75$



$\Theta_{r1} B^{\delta_1} = 0.15,\ \Theta_q B^{-\eta_1} = 1$

Figure 4: The real interest rate as a function of the inflation in the second extension



$\Theta_{r2}B^{\varrho_1} = 0.04$

6 The impact of inflation on the effect of financial liberalization

Having analyzed the effect of financial liberalization and inflation on growth, it is interesting to study how inflation influences the impact of financial liberalization on the real interest rate in the two extension where money is not superneutral.

If money is used in purchasing investment goods, the effect of inflation on financial liberalization can be obtained by taking the total derivative of equation (40). After some algebraic manipulations this yields

$$\left.\frac{d^2r}{dBd\pi}\right|_I = \frac{1}{r}\left[1+\frac{\eta_1\frac{r+\pi}{r}+\eta_2}{\eta_2 q_k(q_k-1)} - \frac{q_k}{q_k-1}\frac{1-\frac{\pi}{r}\frac{dr}{d\pi}}{r+\pi} - \frac{\frac{\eta_1}{q_k}}{\delta_1+\delta_2\eta_1\frac{q_k}{q_k-1}}\right]\frac{dr}{dB}\frac{dr}{d\pi}. \tag{48}$$

As has been shown before, the sign of $dr/d\pi$ is negative while that of dr/dB is positive. Unfortunately, we find that the sign of the expression in the squared bracket is ambiguous. It should be emphasized that the ambiguity does not not come from the assumption that financial superstructure also facilitates transactions on investment purchases; if $\eta_1 = 0$, i.e. no financial superstructure appears in the transaction cost function, equation (48) still remains ambiguous.

In the second extension, that is, money is used as a production factor in the financial sector, the impact of inflation on the growth effect of financial liberalization can similarly be determined by taking the total derivative of equation (40):

$$\left.\frac{d^2 r}{dBd\pi}\right|_{II} = \frac{1}{r} \frac{1 - \dfrac{r}{r+\pi}}{1 + \varrho_2 \dfrac{r}{r+\pi}} \frac{dr}{dB} \frac{dr}{d\pi}. \tag{49}$$

Since $dr/d\pi$ is negative while dr/dB positive, the sign of this expression is negative. This indicates that the effect of financial liberalization on growth is lower at higher inflation rates, that is, high inflation economies will not benefit very much from a liberalization of their financial sector, which corresponds to casual empirism.

7 Concluding remarks

This paper has proposed three variants of a two sector endogenous growth model in order to analyze the relationship between financial liberalization, inflation, and economic growth. In all variants, the sector affecting money demand has been interpreted as the financial sector and money has been modeled as entering into the transaction cost technology of households. In addition to this motivation for the use of money, money has been supposed to influence the transaction costs of investment [in variant two] and also to enter directly into the production function of the financial sector [in variant three].

First, the analysis has shown that financial liberalization is always associated with an increase in the steady state per capita growth rate. However, the size of this effect has been found to be very small if the real interest rate before the liberalization was small. Moreover, the effect of financial liberalization has negatively been related to the rate of inflation when money has been modeled to enter the production of financial superstructure [variant three]. Second, the growth effect of inflation has turned out to be negative in the variant two and three. In particular, this negative effect has also been present when real resources are used in transactions for investment purchases. It should be stressed that money has been assumed to affect only one of the two sectors, the financial sector. Third, the results of some numerical calculation have suggested that if money facilitates the purchasing of investment goods [variant two], then the growth effect of inflation is modest, which contradicts the findings of cross-country regressions. However, if money directly affects the productivity of capital in the financial sector [variant three], substantial negative growth effects of inflation can be generated, which are in line with the empirical regularities.

These results suggest that modeling the role of money as facilitating investment purchases does not add much insight to the existing literature. In contrast, accounting for the role of money in the production process of the financial sector is a plausible modeling alternative that reconciles the results of endogenous growth models with the empirical regularities. However, a more explicit formulation of the financial sector within a growth framework may be necessary to understand the impact of inflation on growth deeper. A promising road for further research may be in the spirit of Lucas's (1993) analysis of the welfare costs of inflation.

Appendix

A The consumer's maximization problem

The current value Hamiltonian for the consumer's problem is

$$\begin{aligned}\mathscr{H}_c = &\frac{c^{1-\theta}-1}{1-\theta}e^{-\rho t}\\ &+\lambda e^{-\rho t}\left((a-m_c)r - \pi m_c - c - T_c\frac{c^{1+\nu_1+\nu_2}}{z^{\nu_1}m_c^{1+\nu_2}}\right)\end{aligned} \tag{A.1}$$

In addition to the consumer's budget constraint (3), this yields the first order conditions

$$\frac{\partial\mathscr{H}}{\partial c} = c^{-\theta} - \lambda\left(1 + T_c\left(1+\nu_1+\nu_2\right)\left(\frac{c}{s}\right)^{\nu_1}\left(\frac{c}{m_c}\right)^{\nu_2}\right) = 0 \tag{A.2}$$

$$\frac{\partial\mathscr{H}}{\partial m_c} = T_c\nu_2\left(\frac{c}{z}\right)^{\nu_1}\left(\frac{c}{m_c}\right)^{1+\nu_2} - r + \pi = 0 \tag{A.3}$$

$$\frac{\partial\mathscr{H}}{\partial a} = \lambda r = -\dot{\lambda} + \lambda\rho \tag{A.4}$$

$$\lim_{t\to\infty}\lambda e^{-rt}a = 0 \tag{A.5}$$

From these equations first order conditions (4a)–(4a) immediately follow.

B The producer's maximization problem in the basic model

The current value Hamiltonian for the producer is given by

$$\mathscr{H}_p = \Big(A_y(\phi_k k)^\alpha(\phi_{zy}z)^{1-\alpha} - i_k\Big)\,e^{-rt} - q_k e^{-rt} i_k + q_m e^{-rt} i_m$$
$$+q_z e^{-rt} B\Big(\big(1-\phi_k-\phi_{ks}\big)k\Big)^\delta \Big(\big(1-\phi_{zy}-\phi_{zs}\big)z\Big)^{1-\delta}, \qquad \text{(B.1)}$$

which yields the first order conditions

$$\frac{\partial \mathscr{H}_p}{\partial i_k} = -1 + q_k = 0, \qquad \text{(B.2)}$$
$$\frac{\partial \mathscr{H}_p}{\partial \phi_k} = \alpha A\left(\frac{\phi_k k}{\phi_{zy} z}\right)^{\alpha-1} k - q_z \beta B\left(\frac{(1-\phi_k)k}{(1-\phi_{zy})z}\right)^{\beta-1} k = 0, \qquad \text{(B.3)}$$
$$\frac{\partial \mathscr{H}_p}{\partial \phi_{zy}} = (1-\alpha)A\left(\frac{\phi_k k}{\phi_{zy} z}\right)^{\alpha} z - q_z(1-\beta)B\left(\frac{(1-\phi_k)k}{(1-\phi_{zy})z}\right)^{\beta} z = 0, \qquad \text{(B.4)}$$
$$\frac{\partial \mathscr{H}_p}{\partial k} = \phi_k \alpha A\left(\frac{\phi_k k}{\phi_{zy} z}\right)^{\alpha-1} + q_z(1-\phi_k)\beta B\left(\frac{(1-\phi_k)k}{(1-\phi_{zy})z}\right)^{\beta-1} = -\dot{q}_k + r q_k, \qquad \text{(B.5)}$$
$$\frac{\partial \mathscr{H}_p}{\partial z} = \phi_{zy}(1-\alpha)A\left(\frac{\phi_k k}{\phi_{zy} z}\right)^{\alpha} + q_z \phi_{zz}(1-\beta)B\left(\frac{(1-\phi_k)k}{(1-\phi_{zy})z}\right)^{\beta} = -\dot{q}_z + r q_z, \qquad \text{(B.6)}$$
$$\lim_{t\to\infty} q_z e^{-rt} z = \lim_{t\to\infty} q_k e^{-rt} k = 0. \qquad \text{(B.7)}$$

Equation (B.3) and (B.4) imply (14a) and (14b), respectively. Substituting (14a) into (B.4) and (14b) into (B.5), and taking into account of (B.2), we get (14c) and (14d).

Solving (14a)–(14d) for r results in (16), where the following definitions are used

$$\Theta_{r0} = \Big(\alpha A\Big)^{\frac{\beta}{1-\alpha+\beta}} \Big(1-\beta\Big)^{\frac{1-\alpha}{1-\alpha+\beta}} \left(\frac{\alpha}{1-\alpha}\frac{\beta}{1-\beta}\right)^{\frac{\beta(1-\alpha)}{1-\alpha+\beta}}, \qquad \text{(B.8)}$$
$$\delta = \frac{1-\alpha}{1-\alpha+\beta}. \qquad \text{(B.9)}$$

C The producer's maximization problem facing transaction costs on investment purchases

The current value Hamiltonian for the producer is given by

$$\mathscr{H}_p = \left(A(\phi_k k)^{\alpha}(\phi_{zy} z)^{1-\alpha} - i_k - T_i \frac{i_k^{1+\vartheta_1+\vartheta_2}}{(\phi_{zi} z)^{\vartheta_1} m_p^{\vartheta_2}} - \pi m_p - i_m \right) e^{-rt}$$
$$- q_k e^{-rt} i_k + q_m e^{-rt} i_m + q_z e^{-rt} B\left((1-\phi_k)k\right)^{\beta}\left((1-\phi_{zy}-\phi_{zi})z\right)^{1-\beta}. \quad \text{(C.1)}$$

This yields the first order conditions

$$\frac{\partial \mathscr{H}_p}{\partial i_k} = -1 - (1+\vartheta_1+\vartheta_2) T_p \left(\frac{i_k}{\phi_{zi} z}\right)^{\vartheta_1} \left(\frac{i_k}{m_p}\right)^{\vartheta_2} + q_k = 0, \quad \text{(C.2)}$$

$$\frac{\partial \mathscr{H}_p}{\partial i_m} = -1 + q_m = 0, \quad \text{(C.3)}$$

$$\frac{\partial \mathscr{H}_p}{\partial \phi_k} = \alpha A \left(\frac{\phi_k k}{\phi_{zy} z}\right)^{\alpha-1} k - q_z \beta B \left(\frac{(1-\phi_k)k}{(1-\phi_{zy}-\phi_{zi})z}\right)^{\beta-1} k = 0, \quad \text{(C.4)}$$

$$\frac{\partial \mathscr{H}_p}{\partial \phi_{zy}} = (1-\alpha) A \left(\frac{\phi_k k}{\phi_{zy} z}\right)^{\alpha} z - q_z (1-\beta) B \left(\frac{(1-\phi_k)k}{(1-\phi_{zy}-\phi_{zi})z}\right)^{\beta} z = 0, \quad \text{(C.5)}$$

$$\frac{\partial \mathscr{H}_p}{\partial \phi_{zi}} = \vartheta_1 T_p \left(\frac{i_k}{\phi_{zi} z}\right)^{1+\vartheta_1} \left(\frac{i_k}{m_p}\right)^{\vartheta_2} z$$
$$- q_z (1-\beta) B \left(\frac{(1-\phi_k)k}{(1-\phi_{zy}-\phi_{zi})z}\right)^{\beta} z = 0, \quad \text{(C.6)}$$

$$\frac{\partial \mathscr{H}_p}{\partial k} = \phi_k \alpha A \left(\frac{\phi_k k}{\phi_{zy} z}\right)^{\alpha-1} + q_z (1-\phi_k) \beta B \left(\frac{(1-\phi_k)k}{(1-\phi_{zy}-\phi_{zi})z}\right)^{\beta-1} = -\dot{q}_k + r q_k, \quad \text{(C.7)}$$

$$\frac{\partial \mathscr{H}_p}{\partial m_p} = \vartheta_2 T_p \left(\frac{i_k}{\phi_{zi} z}\right)^{\vartheta_1} \left(\frac{i_k}{m_p}\right)^{1+\vartheta_2} - \pi = -\dot{q}_m + r q_m, \quad \text{(C.8)}$$

$$\frac{\partial \mathscr{H}_p}{\partial z} = \phi_{zy}(1-\alpha) A \left(\frac{\phi_k k}{\phi_{zy} z}\right)^{\alpha} - \phi_{zi} \vartheta_1 T_p \frac{\left(\frac{i_k}{\phi_{zi} z}\right)^{1+\vartheta_1}}{\left(\frac{m_p}{i_k}\right)^{\vartheta_2}}$$
$$+ q_z \phi_{zz} (1-\beta) B \left(\frac{(1-\phi_k)k}{\phi_{zz} z}\right)^{\beta} = -\dot{q}_z + r q_z, \quad \text{(C.9)}$$

$$\lim_{t\to\infty} q_m e^{-rt} m = \lim_{t\to\infty} q_z e^{-rt} z = \lim_{t\to\infty} q_k e^{-rt} k = 0. \quad \text{(C.10)}$$

(C.4) and (C.5) imply (25a) and (25b), respectively. (25c) follows from equation (C.5) and (C.6). (C.3) and (C.8) yields (25d) while (C.2) implies (25e). Substituting (25a) into (C.9) and (25b), (25c) into (B.5), we get (25f) and (25g).

Solving (26), (25f) and (25g) for r yields (27). Furthermore, (25b)–(25e) and (25g) lead to (28), where the following definitions are used

$$\Theta_{r1} = \left(\alpha A\right)^{\frac{\beta}{1-\alpha+\beta}} \left(1-\beta\right)^{\frac{1-\alpha}{1-\alpha+\beta}} \left(\frac{\alpha}{1-\alpha}\frac{\beta}{1-\beta}\right)^{\frac{\beta(1-\alpha)}{1-\alpha+\beta}}, \tag{C.11}$$

$$\delta_1 = \frac{1-\alpha}{1-\alpha+\beta}, \tag{C.12}$$

$$\delta_2 = \frac{\beta(1-\alpha)}{1-\alpha+\beta}, \tag{C.13}$$

$$\Theta_q = (1+\vartheta_1+\vartheta_2)\left(\frac{T_p A^{\vartheta_1}}{\vartheta_1^{\vartheta_1}\vartheta_2^{\vartheta_2}}\right)^{\frac{1}{1+\vartheta_1+\vartheta_2}} \left(\frac{\alpha(1-\alpha)^{\frac{1-\alpha}{\alpha}}}{\beta(1-\beta)^{\frac{1-\beta}{\beta}}}\right)^{\frac{\alpha\vartheta_1}{1+\vartheta_1+\vartheta_2}}, \tag{C.14}$$

$$\eta_1 = \frac{\alpha}{\beta}\frac{\vartheta_1}{1+\vartheta_1+\vartheta_2}, \tag{C.15}$$

$$\eta_2 = \frac{\vartheta_2}{1+\vartheta_1+\vartheta_2}. \tag{C.16}$$

D The producer's maximization problem using money in the financial sector

The Hamiltonian for the producer's problem is

$$\begin{aligned}\mathscr{H}_p = &\left(A(\phi_k k)^{\alpha}(\phi_{zy}z)^{1-\alpha} - i_k\right)e^{-rt} - q_k e^{-rt} i_k + q_m e^{-rt} i_m \\ &+ q_z e^{-rt} B\Big((1-\phi_k)k\Big)^{\beta_1}\Big((1-\phi_{zy})z\Big)^{\beta_2} m_p^{1-\beta_1-\beta_2}.\end{aligned} \tag{D.1}$$

Taking the derivative of the Hamiltonian with respect to the relevant variables, the following first order conditions can be derived:

$$\frac{\partial \mathscr{H}_p}{\partial i_k} = -1 + q_k \qquad = 0, \tag{D.2}$$

$$\frac{\partial \mathscr{H}_p}{\partial i_m} = -1 + q_m \qquad = 0, \tag{D.3}$$

$$\frac{\partial \mathscr{H}_p}{\partial \phi_k} = \alpha A\left(\frac{\phi_k k}{\phi_{zy} z}\right)^{\alpha-1} k - q_z \beta_1 B \frac{\left(\frac{m}{(1-\phi_{zy})z}\right)^{1-\beta_1-\beta_2}}{\left(\frac{(1-\phi_k)k}{(1-\phi_{zy})z}\right)^{1-\beta_1}} k \quad = 0, \tag{D.4}$$

$$\frac{\partial \mathscr{H}_p}{\partial \phi_{zy}} = (1-\alpha)A\left(\frac{\phi_k k}{(1-\phi_{zy})z}\right)^{\alpha} z$$

$$-q_z\beta_2 B\left(\frac{(1-\phi_k)k}{(1-\phi_{zy})z}\right)^{\beta_1}\left(\frac{m}{(1-\phi_{zy})z}\right)^{1-\beta_1-\beta_2} z = 0, \tag{D.5}$$

$$\frac{\partial \mathscr{H}_p}{\partial m_p} = -\pi + q_z(1-\beta_1-\beta_2)B\frac{\left(\frac{(1-\phi_k)k}{\phi_{zz}z}\right)^{\beta_1}}{\left(\frac{m}{(1-\phi_{zy})z}\right)^{\beta_1+\beta_2}} = -\dot{q}_m + rq_m, \tag{D.6}$$

$$\frac{\partial \mathscr{H}_p}{\partial k} = q_z(1-\phi_k)\beta_1 B\frac{\left(\frac{m}{(1-\phi_{zy})z}\right)^{1-\beta_1-\beta_2}}{\left(\frac{(1-\phi_k)k}{(1-\phi_{zy})z}\right)^{1-\beta_1}}$$

$$+\phi_k\alpha A\left(\frac{\phi_k k}{(1-\phi_{zy})z}\right)^{\alpha-1} = -\dot{q}_k + rq_k, \tag{D.7}$$

$$\frac{\partial \mathscr{H}_p}{\partial z} = \phi_{zy}(1-\alpha)A\left(\frac{\phi_k k}{(1-\phi_{zy})z}\right)^{\alpha}$$

$$+q_z\phi_{zz}\beta_2 B\left(\frac{(1-\phi_k)k}{(1-\phi_{zy})z}\right)^{\beta_1}\left(\frac{m}{(1-\phi_{zy})z}\right)^{1-\beta_1-\beta_2} = -\dot{q}_z + rq_z. \tag{D.8}$$

(36a) and (36a) follow from (D.4) and (D.5), respectively. Using (D.3) and (D.6), we get (36c). (D.2), (D.4), and (D.7) yield (36d), while (D.5) and (D.8) imply (36e).

In (38) the following definitions are used

$$\Theta_{r2} = \left(\left(\alpha A\right)^{\frac{1-\beta_2}{1-\alpha}}\beta_2\left(\frac{\alpha}{1-\alpha}\frac{\beta_2}{\beta_1}\right)^{\beta_1}\left(\frac{1-\beta_1-\beta_2}{\beta_2}\frac{1-\alpha}{\alpha}\right)^{1-\beta_1-\beta_2}\right)^{\varrho_1}, \tag{D.9}$$

$$\varrho_1 = \frac{1-\alpha}{(1-\alpha+\beta_1)+\alpha(1-\beta_1-\beta_2)}, \tag{D.10}$$

$$\varrho_2 = \frac{(1-\beta_1-\beta_2)(1-\alpha)}{(1-\alpha+\beta_1)+\alpha(1-\beta_1-\beta_2)}. \tag{D.11}$$

It is not obvious from (D.11) why ϱ_2 should be smaller than one. However, if we rewrite to

$$\varrho_2 = \frac{1}{\frac{1-\alpha+\beta_1}{(1-\beta_1-\beta_2)(1-\alpha)} + \frac{\alpha}{1-\alpha}}, \tag{D.12}$$

a sufficient condition can be found. If $\alpha > 1-\alpha$ then the denominator of the expression is greater than one, implying that $\varrho_2 < 1$. Since the elasticity of output with respect to capital, α, is likely to be greater than the elasticity of output with respect to financial superstructure, the condition is probably satisfied.

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